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Understanding the Nature of the Low-energy Enhancement in the Photon Strength Function of ^{56}Fe.

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ATLAS Experiment 1564

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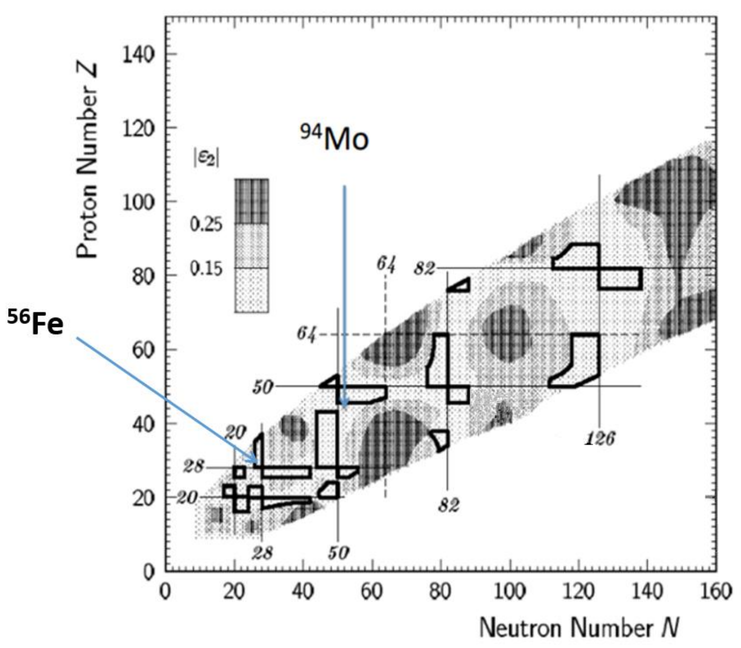
Abstract

A recent experiment designed to determine the multipolarity and electric or magnetic character of transitions in the region of the photon strength function (PSF) enhancement in ^{56}Fe was performed at ATLAS using GRETINA in combination with the Phoswich wall. A beam of 16 MeV protons impinged upon a 1 mg/cm^2 ^{56}Fe target, inelastically exciting it to high energies. The scattered protons were then measured by the Phoswich wall, providing the entrance excitation energy, while the resulting γ-ray cascades were measured in GRETINA. The PSF can be extracted using two-step cascades from the quasi-continuum to specific low-lying levels by a model independent method first employed in ^{95}Mo [1]. This method is being extended to take advantage of GRETINA as a polarimeter to obtain angular and polarization information in the region of the low-energy enhancement of the PSF.

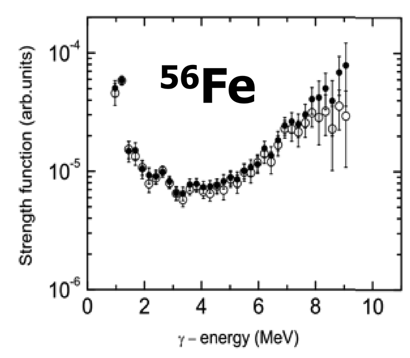
Motivation

The Photon Strength Function (PSF) is a useful tool for describing γ-ray absorption and emission in the quasi-continuum. The recent discovery of a low-energy enhancement in the PSF of medium mass nuclei, such as ^{56}Fe and ^{95}Mo, has sparked great interest because of its potentially large impact on r-process nucleosynthesis as well as other applications.

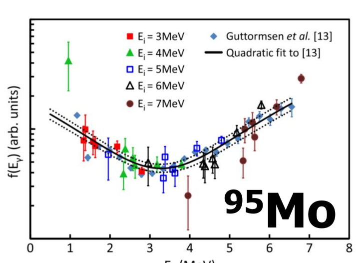
- The enhancement is predicted to occur in regions where magnetic rotation is expected.



S. Frauendorf et. Al. AIP Conference Proceedings 1619, 81 (2014)

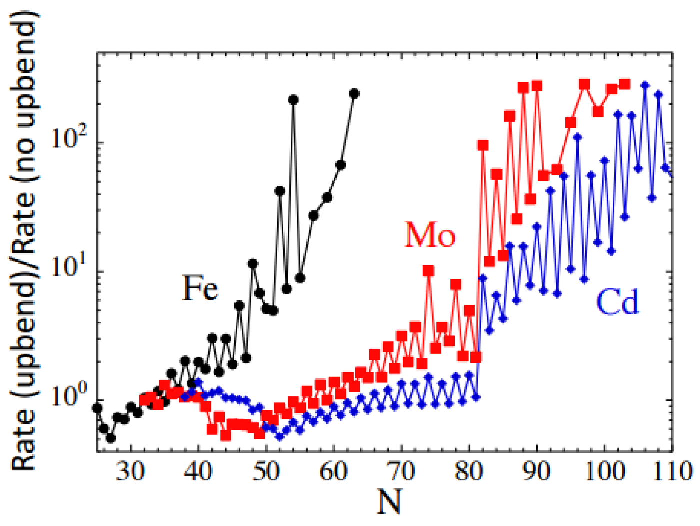


A.V. Voinov et. al. PRC 74, 014314 (2006)

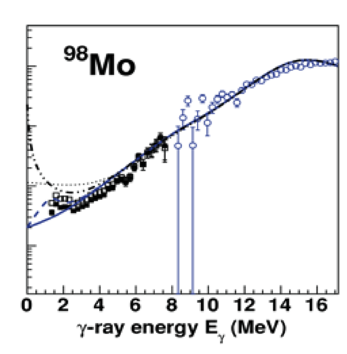


M. Wiedeking et al., PRL 108, 162503 (2012)

- The enhancement could greatly affect r-process reaction rates!

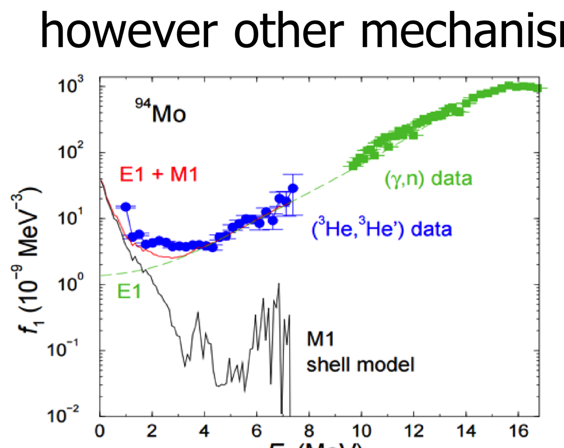


A.C. Larsen et. al. PRC 82, 014318 (2010)

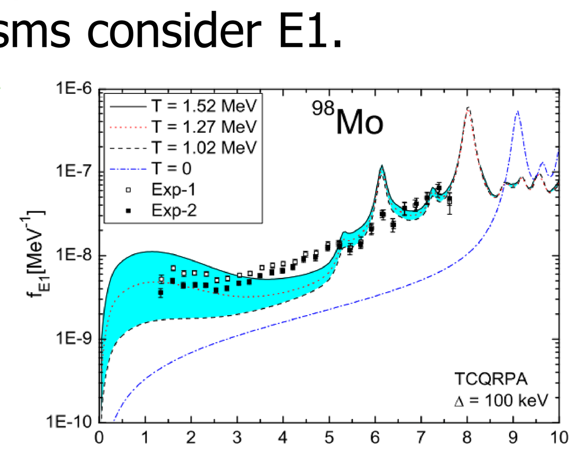


A.C. Larsen et. al. PRC 82, 014318 (2010)

- Shell model calculations predict M1 radiation, however other mechanisms consider E1.



S. Frauendorf et. al. AIP Conference Proceedings 1619, 81 (2014)



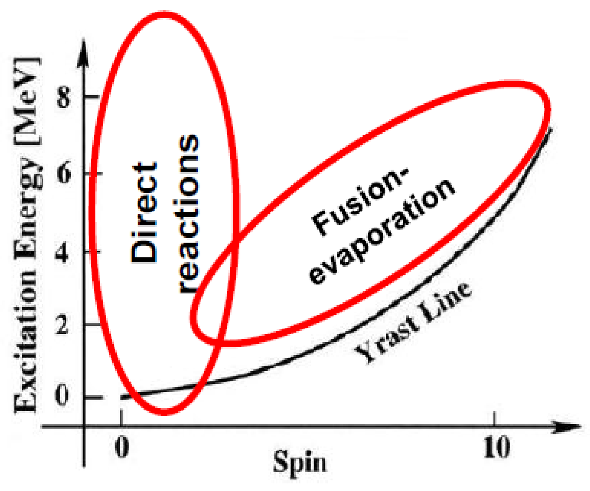
E. Litvinova et. al., PRC 88, 031302 (R) (2013)

- Previous measurement has shown the enhancement is dipole, however the M1 or E1 nature remains unknown.

A polarization measurement is necessary!

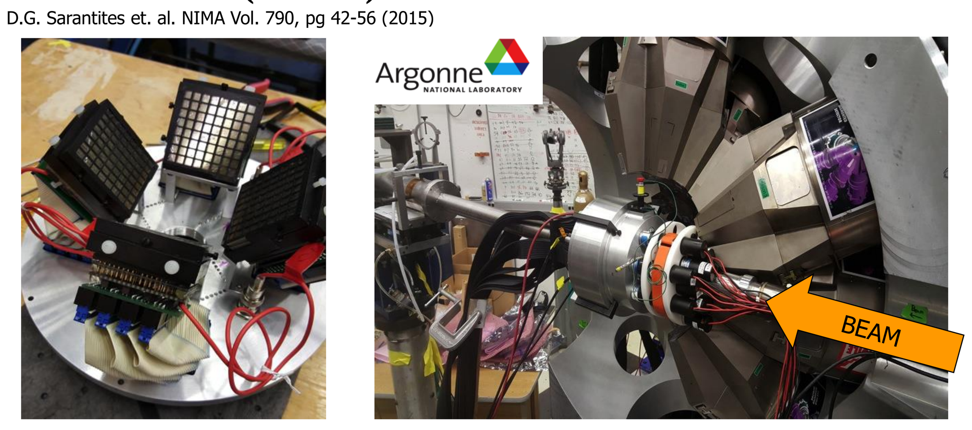
Experimental Method and Analysis

- Use a direct reaction to populate states in quasi-continuum.
- Extract PSF using a new model independent method [1].
- Use GRETINA as a polarimeter to measure the M1 or E1 character in the region of the enhancement.

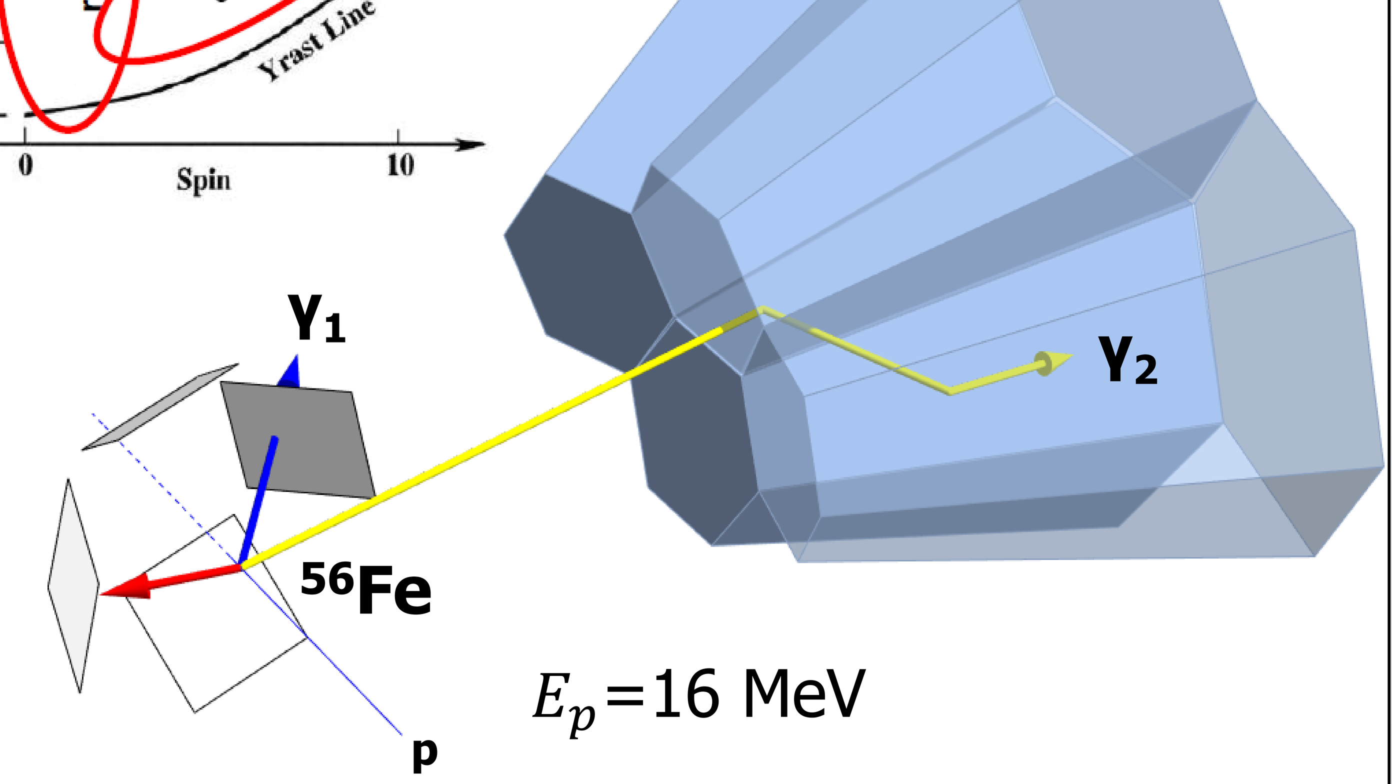


Phoswich Wall (WashU)

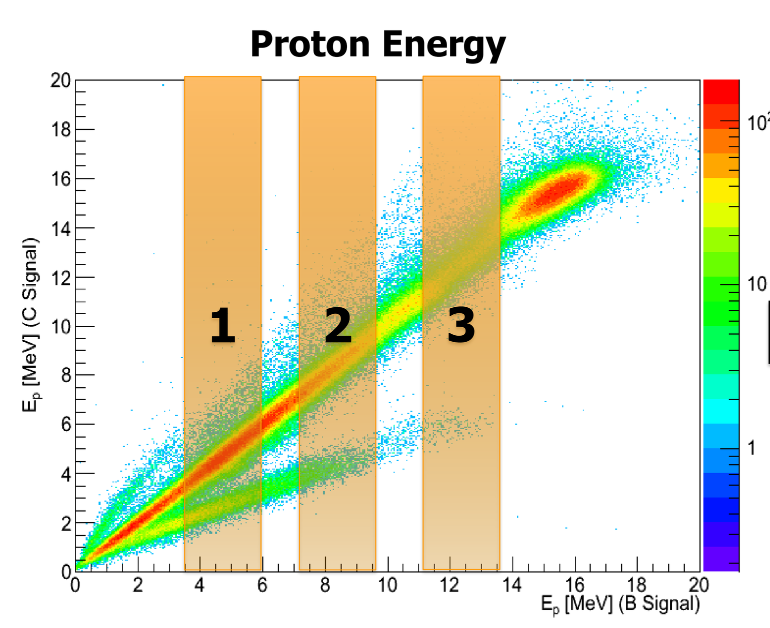
D.G. Sarantites et. al. NIMA Vol. 790, pg 42-56 (2015)



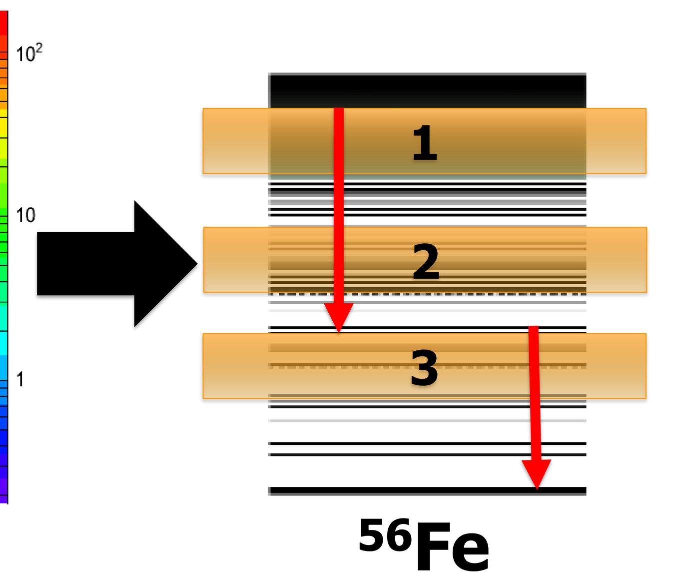
- ^{56}Fe(p,p') performed at ANL

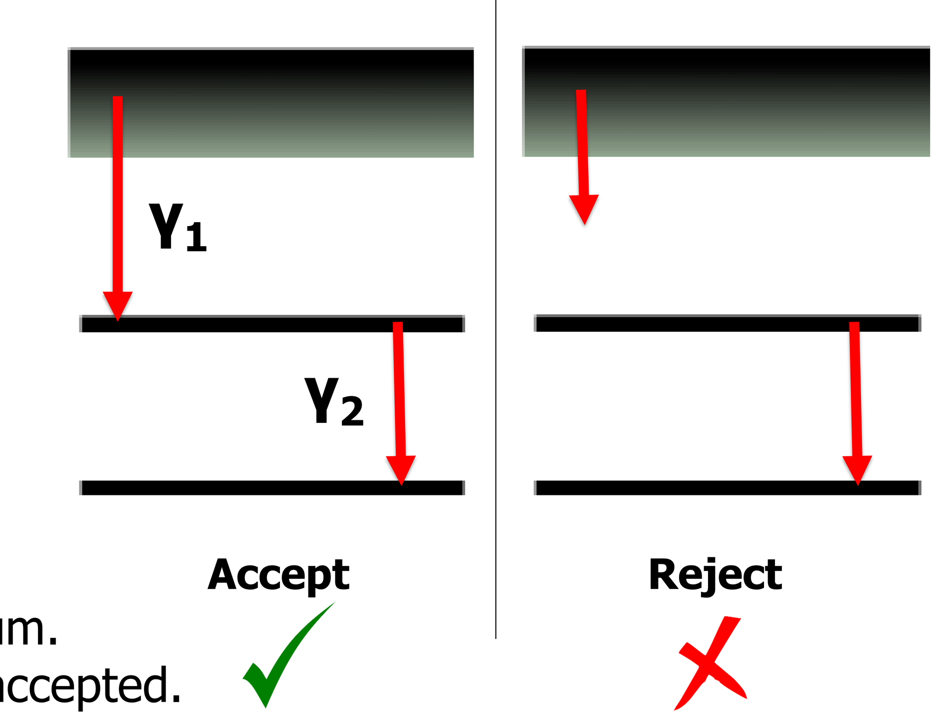


E_p=16 MeV



Extraction of PSF





- Gating on the proton energy selects a region of the quasi-continuum.
- Only events whose energy sum to the total excitation energy are accepted.
- Shape of the PSF can be extracted by ratios of feeding intensities from the quasi-continuum to specific low-lying states of identical spin-parity.

$$f(E_\gamma) \equiv f_{J^\pi}(E_\gamma) = \frac{\Gamma_J(E_x, E_\gamma)\rho_J(E_x)}{E_\gamma^{2\lambda+1}}$$

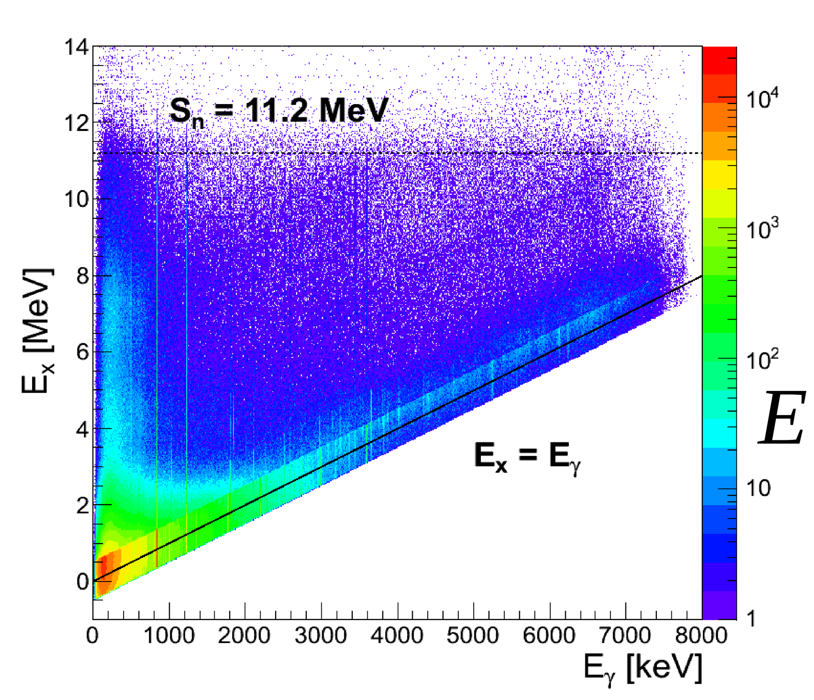
$$N_L(E_x) \propto f(E_\gamma) E_\gamma^3 \Sigma \sigma_J(E_x)$$

$$R = \frac{f(E_x - E_{L1})}{f(E_x - E_{L2})} = \frac{N_{L1}(E_x)(E_x - E_{L2})^3}{N_{L2}(E_x)(E_x - E_{L1})^3}$$

Model independent!

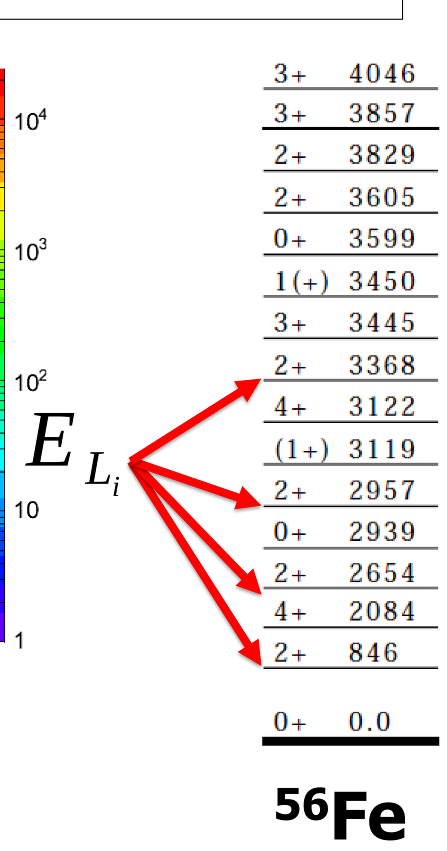
Results

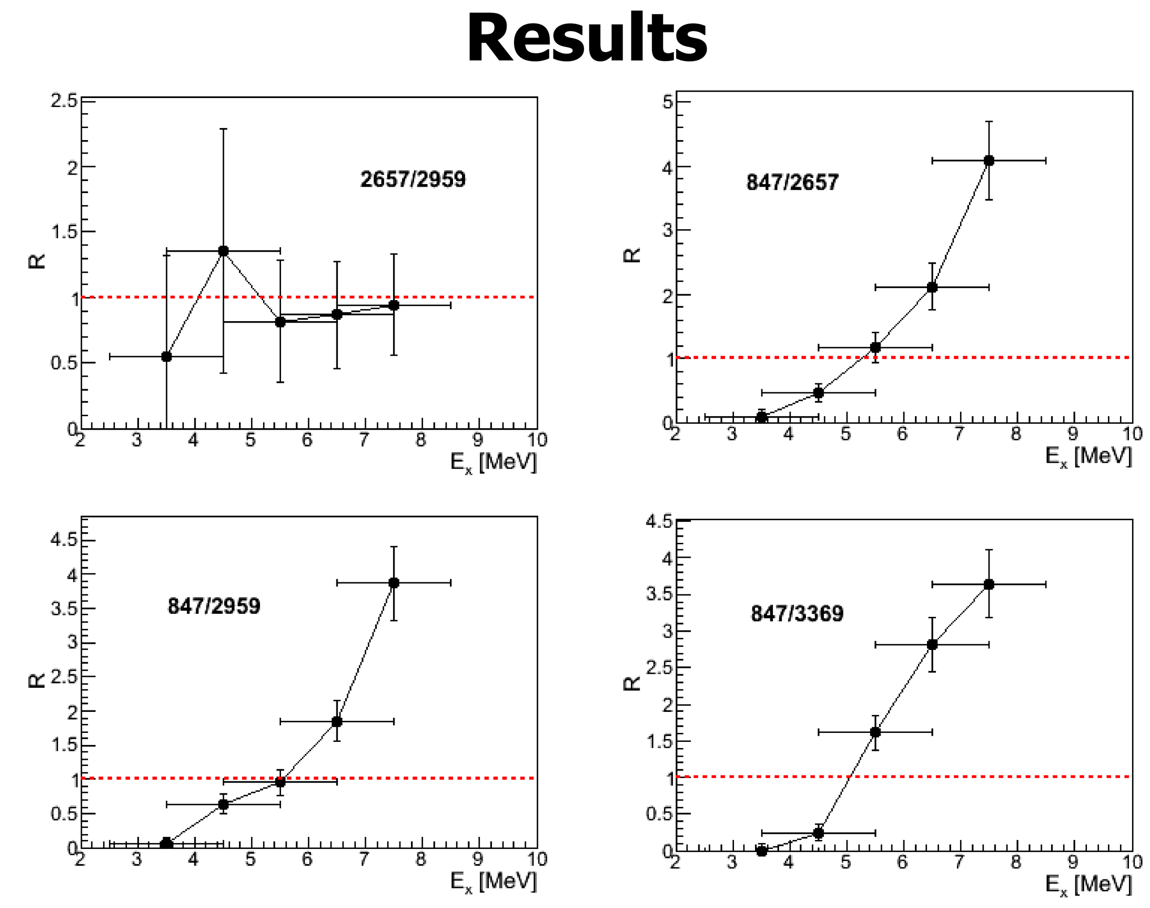
Using the first four 2+ states in 56Fe, the preliminary ratios show consistency with the Brink-Axel hypothesis and the PSF agrees well with previous data taken at Oslo. The next step is to obtain the polarization in the region of enhancement.



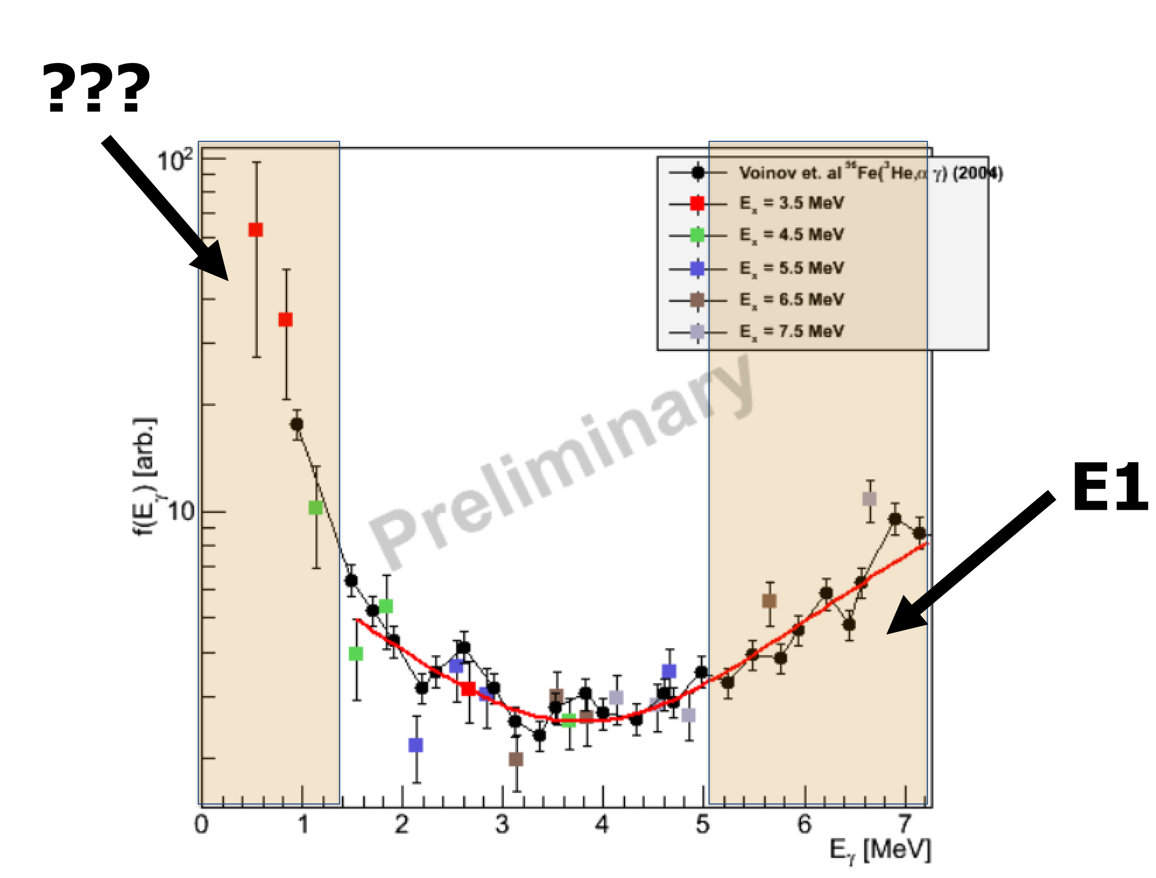
- Calorimeter sorted data:

$$\Sigma E_\gamma = E_x \pm 500\, keV$$





- Rising ratios with increased excitation (E_x) indicate a local minimum in the PSF if they cross R = 1.



- The use of GRETINA as a polarimeter will determine the E1 or M1 nature of the low energy up-bend.

References:
[1] M. Wiedeking et al., PRL 108, 162503 (2012)

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